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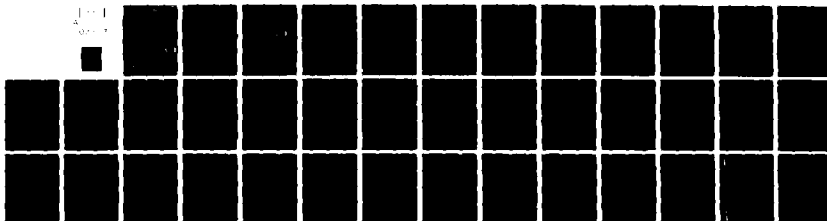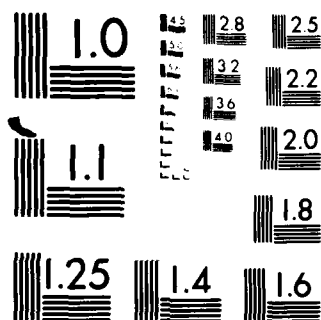   1980   A GHOSHAL   F33615-79-M-5158
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A Forecasting Model for Exchange Rate Changes.

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University of Notre Dame

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study develops a discriminant analysis model to predict changes in exchange rates of foreign currencies over the medium term. Using annual economic data for 20 major countries for the years 1972 through 1978, the study identified relevant economic variables which correctly classified the currency of a country as appreciating or depreciating against the U.S. dollar one year in the future. Because annual data are available in April, the model would give approximately eight months early warning. Four variables, international reserves, money

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20. supply, price levels, and current balance of payments were found to have significant explanatory power. The model determined approximate weights for each variable. Overall, the model had a prediction accuracy of 75% per unit. A holdout sample of predictions for 1979 had a classification accuracy of 80%. per cent.

The model predicts only the direction of exchange rate change one year in the future. It does not consider the magnitude of change nor movements in exchange rates during the year. An attempt at a three-way classification to isolate currencies which changed less than ten per cent gave a relatively low classification accuracy of 55 per cent.

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SUMMARY

A Forecasting Model for Exchange Rate Changes

Animesh Ghoshal

Floating exchange rates have permitted currency values to fluctuate widely from year to year, adding a significant risk component to international transactions. Since the United States sells over $1 billion of arms a year to NATO Allies and buys about $100 million of arms from them, currency management techniques are of considerable relevance for the Department of Defense. This paper is directed to the task of predicting currency movements over the medium term.

Currency forecasting can be successful if lagged relationships exist between underlying economic variables and the actual exchange rate. In this study, a one-year lag is used, which is the appropriate time frame for most international business transactions. Annual economic data for 1972-78 from 20 OECD countries, most of which have security treaties with the U.S., are used to predict currency movements a year ahead. The technique used is discriminant analysis, which enables us to classify countries into two or more mutually exclusive groups. The major part of the study is concerned with 2-group classification, i.e., whether a currency is likely to appreciate or depreciate with respect to the U.S. dollar. An approach to 3-group classification, i.e., whether a currency is likely to appreciate 10% or more, depreciate 10% or more, or change less than 10%, is also made.

The results indicate that the method is quite successful in identifying currencies likely to appreciate and depreciate. The

overall classification accuracy is 75%, well above what would have been expected by chance. The economic variables which turn out to have significant discriminating power are, in order of importance, relative rates of inflation, relative changes in international reserves, relative performance of the current account of the balance of payments, and relative changes in the money supply.

The model appears to be of considerable practical value. The medium term time horizon makes it appropriate for budgetary purposes. It predicts the direction, but not the extent, of currency movements quite well. Most importantly, the forecasts do not hinge on the ability to forecast independent variables, since the forecast for a year is based on economic variables from previous years, all of which are known by April, thus giving at least 8 months early warning of likely changes in exchange rates.

The model is quite simple to use for managerial purposes. A discriminant function is calculated by computer, assigning weights to each of the four economic variables used as predictors. Once the values of these variables are known (by April for any given year) for a currency, these can be substituted into the discriminant function to get the discriminant score for the currency. This can be done by hand, and the score enables us to classify a currency as "likely to appreciate" or "likely to depreciate" in a given year. This information is useful during the negotiation of a foreign purchase or sales contract, and can help in (a) setting a price, and (b) setting the currency of denomination. It can also be used after a contract has been signed, in the timing of billings and payments. Finally, the model can be updated each year, with new information going into the discriminant function.

A FORECASTING MODEL FOR EXCHANGE RATE MOVEMENTS

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A Forecasting Model for Exchange Rate Movements

1. The Nature of the Problem

The U.S. government currently sells about $1 billion of arms to its NATO allies and buys about $100 million of weapons from them. Both figures are likely to grow, particularly because of the recent efforts to improve the coordination of arms among NATO members. With the June 1975 F16 contract, weapons production has in fact became a multinational enterprise. In addition, the U.S. government incurs regular expenditures in the maintenance of overseas bases, generally paid in foreign currency. Thus, currency fluctuations have considerable impact on both revenues and expenditures, and currency management techniques used in international business should be of some value to the Department of Defense.

Since the advent of floating exchange rates among the major currencies in 1973, currency values have experienced enormous fluctuations within relatively short time frames. The fluctuations have been particularly marked for the currencies of the NATO countries. Taking 1978 as an example, in terms of the U.S. dollar, the German mark rose 16%, the Dutch guilder rose 15%, the French franc rose 12%, and the British pound rose 7% between January and December, while the Canadian dollar fell 8%. Among the non-NATO countries which might be of interest in the acquisitions and sales area, the currencies of Japan and Switzerland

both appreciated 23% against the dollar, and the currency of Australia showed no significant change.

Such fluctuations in currency values add a significant risk component to international transactions. If the U.S. had made a commitment at the beginning of 1978 to purchase certain German products, to be delivered and paid for in marks at the end of the year, the change in currency values would have caused a cost over-run of 16%. (If the transaction had been denominated in dollars, the German seller would have taken a loss.) On the other hand, a similar purchase agreement with a Canadian seller, denominated in Canadian dollars, would have caused cost saving of 8%. The same kind of risk, of course, also applies to foreign sales of U.S. goods and services. Thus, a model which provides early warning of exchange rate changes is very desirable for parties engaged in international transactions.

Successful currency forecasting is possible where lagged relationships exist between changes in underlying economic variables and the actual exchange rate. A number of studies have used the balance of payments, reserves, borrowings, relative inflation rates, etc. as explanatory variables. The specific techniques used have ranged from highly sophisticated mathematical models to opinion gathering and "gut feel." In this study, we use a relatively simple statistical technique, discriminant analysis, and readily available economic data, to assist decision makers in foreign exchange risk management.

Our primary objective is to classify countries of interest into two categories:

(a) those whose currencies are likely to appreciate against
   the U.S. dollar, and

(b) those whose currencies are likely to depreciate against
   the U.S. dollar.

The time frame used is one year, i.e., the model is designed
to provide one year's warning of likely changes in exchange
rates. While quite arbitrary, the one year horizon appears
short enough to be of practical value for most international
transactions and long enough for underlying economic forces to
prevail over governmental efforts to resist currency realignment.

The technique used, discriminant analysis, does not enable
us to predict the amount of change in the value of a currency,
but only the probable direction of the change. If the currency
is likely to change by a very small amount in terms of the U.S.
dollar, it might not be worthwhile to take steps to cover against
such a change. It may, therefore, be desirable to establish a
"threshold of significance," e.g., a 10% change. Thus, our
second objective is to classify our contries into three groups:

(a) those whose currencies are likely to rise 10% or more
   against the U.S. dollar,

(b) those whose currencies are likely to fall 10% or more
   against the U.S. dollar, and

(c) those whose currency values are unlikely to change by
   more than 10%.

2. The Technique

Multiple discriminant analysis is very useful for such
classification. It is used in many financial institutions for

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predictive purposes, particularly for evaluating consumer credit,
the capital adequacy of commercial banks, and the likelihood of
corporate bankruptcy. The objective is to classify a given
population into two or more mutually exclusive groups. The
basic technique is to identify the variables or characterisics
which differentiate the groups and assign these characteristics
weights such that a linear combination can be obtained which dis-
criminates best between the groups. The pattern of weights indi-
cates how much each factor contributes, and in which direction,
to the differentiation between the two groups. The entire profile
of characteristics and their interactions is considered. This
is one of the major advantages of multivariable analysis: we
get a more accurate picture of the nature of group differences
in terms of a given set of variables than we would by looking at
each variable separately with no regard for their interactions
and partly overlapping information.

The linear combination mentioned above is expressed as:

$$Z = W_1X_1 + W_2X_2 + W_3X_3 + \ldots\ldots$$

where Z is the discriminant score, the X's represent the inde-
pendent variables, and the W's represent the weights to be assigned
to the variables. The mean value of the Z-score for each group,
known as the centroid, is calculated, and a comparison of group
centroids shows how far apart the groups are along a vector
representing the linear combination. (A geometric representa-
tion is given in Appendix 1.) One can then determine whether
statistically significant differences exist between the groups,
and if so, which of the independent variables account for most

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of the differences. The technique can be used for _analyzing_ differences between groups whose membership is known, or _predicting_ which group an individual observation should be in, based on known values for its independent variables.

The discriminant function can be derived using either of two methods. The _direct_ method considers all the independent variables simultaneously, and is appropriate when the major objective is to get the best "fit," regardless of the discriminating power of each independent variable. The _stepwise_ method enters independent variables one at a time, beginning with the single best discriminating variable, then the one best able to improve the discriminating power of the function in conjunction with the first variable, and so on, until all significant variables have been included. By the process of sequential selection, variables which do not improve the discriminating power of the function are eliminated, and a reduced set left.

After calculating the discriminant function, it can be checked for its discriminating power. By convention, the function is discarded unless it is significant at the 0.05 (5%) level or better.

3. Design of the Study

The data base was constructed using annual figures published by the International Monetary Fund and the Organization for Economic Co-operation and Development (OECD)[1] for 20 countries listed in Table 1, as well as the U.S., over the years 1972-79. All countries included had reasonably flexible exchange rates (year-end exchange rates for the years 1974-1979 are shown in

Table 2) and readily available economic data comparable across them. Most countries in the group have security treaties with the U.S.[2] The world's most heavily traded currencies are all included in the analysis.

For each of the 6 years 1974 to 1979, the 20 countries were first divided into two groups--those whose currencies had appreciated against the dollar and those whose currencies had depreciated.[3] Overall, there were 69 appreciations and 51 depreciations; for particular years, of course, the proportions varied.

Our dependent variable is whether in a particular year a country belongs in the appreciating or depreciating group. The independent variables were selected with two criteria in mind: first, there should be a logical reason for the variable to affect the exchange rate, and second, data regarding the variable should be readily available. Using results of previous research in this area, as well as simple economic theory, 6 variables were selected.

1. International reserves. Trends in reserves should be an indicator of a country's past external economic performance, and of its ability to maintain its currency value in the future. This is applicable even in a world of floating exchange rates, since governments frequently enter the foreign exchange markets to support currencies.

2. Money supply. A rapid increase in a country's money supply, relative to other countries, is likely to hurt the balance of payments, both in the trade account and in the capital

account, and thereby reduce the demand for the country's currency in the world market.

3. Price index. According to the purchasing power parity theory, the change in the exchange rates between two countries over a period of time should equal the relative change in the price levels of those countries over the same period of time. Although there are many theoretical objections against this theory for short run analysis, relative price changes can be good indicators of exchange rate changes if they are of substantial magnitude.

4. Discount rate. Many countries have tried to support their currencies by tightening monetary policy, hoping to attract short term capital inflows. While short term money market rates would be more appropriate, they are not always available in comparable form. In any case, changes in the central bank discount rate should be good proxies for changes in money market rates.

5. Trade performance. Exports relative to imports are very important in the balance of payments of most countries. Poor export performance should lead to downward pressure on a country's currency.

6. Current balance. The current account in the balance of payments consists of the net balance of imports and exports of goods as well as services, plus unilateral transfers like gifts and remittances. The current balance is a good indicator of a country's external economic performance, and is closely watched by currency analysts.

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In this study, all variables used are in the form of
growth rates rather than numerical quantities (e.g., we use
the rate of growth of reserves for each country). This re-
duces the effects of scale and makes countries of different
economic size comparable. For each country, each ratio is
divided by the corresponding one for the U.S., since we are
interested in the performance of each currency against the U.S.
dollar.

If the model is to be useful for prediction, the economic
variables used must be from a period earlier than the one for
which the currency forecast is being made. A one-year lag was
used, i.e., we examined the relationship between changes in the
independent variables over one calendar year and changes in
currency values over the next calendar year. As a specific
example, the rates of change in the independent variables between
December 1972 and December 1973 were used to explain the change
in currency values in the year 1974.[4]

4. Computation

The Statistical Package for the Social Sciences (SPSS)
Discriminant Analysis program was used in our calculations. (The
program is given in Appendix 2.) Currency changes for the twenty
countries over each of the years 1974 to 1979 were tested sepa-
rately, using economic data from the years 1972-73 to 1977-78.
Both direct and stepwise methods were used. Finally, the process
was repeated using all the years together, instead of a year at
a time.

The discount rate was found to have no significant explanatory power. Moreover, in some cases its sign was positive, in others negative. This is perhaps because a rise in the discount rate may reflect either the presence of balance of payments problems or the implementation of economic policies to strength a currency. In any event, since the discriminating power was negligible, the discount rate was dropped as an independent variable.

The trade performance variable (exports relative to imports), while having a positive sign (as expected) in practically all cases, turned out to have negligible discriminating power when used in conjunction with the other variables. This may be due to its overlap with both the reserves variable and the current account variable. It, too, was therefore dropped.

For the other four variables, mean values of the 120 observations from the 6-year period as a whole are presented below.

	Group 1 Appreciating Currencies (69)	Group 2 Depreciating Currencies (51)
Reserves at official value (R)	1.2084	0.9508
Money Supply (M1)	1.0539	1.0984
Consumer Prices (P)	1.0209	1.0620
Current Balance (C)	-261.6	-1704.2

All values, as explained earlier, are derived from rates of change relative to the U.S.[5]

It can be seen that the "appreciating" countries, as a group, have had a more rapid growth of international reserves, a slower

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growth in money supply, lower inflation[6], and a better current
balance, as one would expect.

On carrying out the discriminant analysis, all of the
four variables were found to have significant discriminating
power in a multivariate framework. Thus, the results of the
direct and stepwise methods are identical. In unstandardized
form, we have the discriminant function:

$$Z = 11.25563 + 1.00719R - 3.65752M1 - 8.03142P + 0.00011C \qquad (1)$$

Here we can multiply raw values of the variables associated
with an observation by the corresponding weights to obtain its
discriminant score directly. However, the weights do not repre-
sent discriminating power; that is obtained from the standardized
form of the function, where the mean discriminant score for all
observations is 0 and the standard deviation is one. The
standardized form of our discriminant function is:

$$Z = 0.48600R - 0.31368M1 - 0.54628P + 0.35743C \qquad (2)$$

Each weight now represents the relative contribution of its
associated variable to the separation of the two groups. The
centroids are 0.38935 and -0.52679 for the appreciating and
depreciating groups respectively, and the function is significant
at the 0.001 level.

5. Validation

Since the model discriminates significantly between the
two groups, we can now examine how well it classifies each country.
The results for individual years and countries are shown in Table
3. They can be summarized in a classification matrix:

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| | | Predicted Group Membership | |
Actual Group	No. of Cases	Group 1	Group 2
Group 1 (Appreciating)	69	54 (78.3%)	15 (21.7%)
Group 2 (Depreciating)	51	15 (29.4%)	36 (70.6%)
Total Cases	120		

The model has correctly classified 54 of the 69 appreciations, and 36 of the 51 depreciations, for an overall classification accuracy of 75%.

The most rigorous test of the predictive power of the model, however, would be in developing the function on one group (the analysis sample) and testing it on a second group (the holdout sample). This is because an upward bias in the prediction accuracy will arise if the same observations are used to develop and test the function. Accordingly, currency changes over the year 1979 are used as the holdout sample to test the validity of the model for prediction. Here, the discriminant function is developed for currency changes over the five year period 1974-78, and used to predict the direction of currency change in 1979. The relevant independent variables for 1977-78 are then entered into the model, which uses them and the weights derived from the analysis sample to classify the countries in the holdout sample.[7]

The results are presented in Table 4. They can summarized in the following classification matrix:

	No. of Cases	Predicted Group Membership	
Actual Group		Group 1	Group 2
Group 1 (Appreciating)	13	13 (100%)	0 (0%)
Group 2 (Depreciating)	7	4 (57.1%)	3 (42.9%)

The model has correctly predicted all 13 appreciations, and 3 of the 7 depreciations in 1979. The overall classification accuracy is 80%.

The 80% ratio is quite high, but it should be compared with the a priori chance of classifying countries correctly without our disriminant function. Since the majority of the classification sample (56 out of 100) belonged to group 1, we could have arbitrarily assigned all 20 members of the holdout sample to group 1, and achieved a classification accuracy of 65% for 1979. However, the objective of our research is not solely to predict the number of appreciations and depreciations, but to identify correctly members of both groups. The proportional chance criterion is the appropriate model to use here, and is given by:

$$C = P^2 + (1-P)^2$$

where C = proportional chance criterion

P = proportion of observations in Group 1

1-P = proportion of observations in Group 2

Substituting the appropriate numbers, we get

$$C = (.56)^2 + (.44)^2$$

$$= .5072$$

It may be concluded that unless the discriminant function achieves a classification accuracy higher than 50.72%, it should be considered unacceptable. No rigorous guidelines have been developed in the literature, but as a general rule of thumb, an accuracy of 25% greater than the proportional chance criterion is considered quite good. Our model's accuracy of 80% is well above this threshold.

6. Interpretation

Since the discriminant function is statistically significant and the classification accuracy is acceptable, we can now try to make substantive interpretation of the findings. We can do this by examining the signs and magnitudes of the standardized discriminant weights attached to each variable in Equation 2, which is repeated below:

$$Z=0.48600R-0.31368M1-0.54628P + 0.35743C$$

As mentioned earlier, in standardized form, independent variables with relatively larger weights contribute more to the discriminating power of the function. The sign indicates whether the variable makes a positive or negative contribution. It is seen that the price variable makes the largest contribution, followed by reserves, current balance, and money supply.

7. An Approach to 3-Group Classification

As mentioned in Section 1, it may be desirable to establish a threshold of significance for currency changes. Using a 10% threshold, we classify the 120 observations into three groups: appreciations of 10% or more, changes of less than 10%, and depreciations of 10% or more. Mean values of the variables for the 3-groups are presented below:

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	Group 1 App. 10% or more (32)	Group 2 Change less than 10% (70)	Group 3 Dep. 10% or more (18)
R	1.2722	1.0481	0.9883
M1	1.0400	1.0819	1.0961
P	1.0019	1.0349	1.1167
C	-155.0	-1269.9	-617.2

The relative values of the means for reserves, money supply, and prices are as expected; however, the mean current balance figure for the countries in Group 2, which have had currency depreciations of less than 10%, is lower (worse) than the figure for Group 3.

Carrying out a stepwise discriminant analysis, we have the primary discriminant function, in standardized form, given by:

$$Z = -0.31429R+0.01127M1+0.94268\ P \qquad (3)$$

The current balance variable turns out to have negligible discriminating power, and is dropped. The price variable is the most significant.[8] The group centroids are -0.62243, -0.01391, and 1.16081 for Groups 1, 2, and 3 respectively, and the function is significant at the 0.001 level. The accuracy of the classification is shown in the following matrix:

Actual Group	No. of Cases	Predicted Group Membership Group 1	Group 2	Group 3
Group 1 (App. $\geq$ 10%)	32	21 (65.6%)	10 (31.3%)	1 (3.1%)
Group 2 (Change < 10%)	70	24 (34.3%)	35 (50%)	11 (15.7%)
Group 3 (Dep. $\geq$ 10%)	18	2 (11.1%)	6 (33.3%)	10 (55.6%)

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The model has an overall classification accuracy of 55%. Although there are only 3 gross errors (classifying countries in Group 1 as belonging to Group 3 or vice-versa), it seems that the classification accuracy could be improved with further research.

8. Managerial Use

This section discusses how the model can be used by financial managers. The major practical use for the Department of Defense will be in choosing the currency in which various foreign transactions are denominated, and in the timing of payments and billings for such transactions.

As mentioned earlier, the economic variables used in forecasting currency movements over a given year are available by April. These can then be inserted into Equation (1) to get the Z values for each country. The Z score determines whether a country's currency is predicted to appreciate or depreciate.[9] As can be seen from the computer printout (Appendix 3), all countries predicted to be in the appreciating group have Z-scores of -0.026 or more; all countries predicted to be in the depreciating group have Z-score of -0.079 or less. The higher the Z-score, the greater is the probability of appreciation, and vice versa.

"Depreciating"   "Appreciating"

-.079   -.026 0

As an example, we can use the model to "predict" the movement of the British pound over 1980. At the end of 1979, the pound was worth $2.224. By April 1980, all the relevant economic

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variables were available: R was 1.328, M1 was 1.028, P was 1.019, and C was 608. (That is, Britain's reserves had grown more rapidly than those of the U.S., the money supply and prices rose more rapidly as well, and the current balance--compared to historical experience--had performed better.) Substituting these values into Equation (1), we have the Z-score for Britain:

$$Z = 11.25563+1.00719R-3.65752M1-8.03142P+0.00011C$$

$$= 11.25563+(1.00719)(1.328)-(3.65752)(1.028)-(8.03142)(1.019)$$
$$+ (0.00011)(608)$$

$$= 0.71611$$

Since this is well above the critical point for appreciation, the model prediction is that by the end of 1980, the pound should appreciate above its end-of-1979 value.

The actual value of the pound on April 15, 1980, was $2.198. It had risen to $2.32 in mid-February, fallen to $2.14 in early April, then risen again. Such short term fluctuations are ignored in our model, which uses fundamental economic factors and has a medium term (one-year) time horizon; in the case of Britain, these factors indicate that the pound should be worth more than $2.224 at the end of 1980. (As a matter of interest, in mid-November the pound stood at $2.41.)

Foreign Purchases: Let us consider a contract for the purchase of radar equipment from Britain for ₤100 million, or $219.8 million at the exchange rate in mid-April. If, on the basis of all available information--including but not limited to this model--the pound is expected to rise above $2.198, the U.S. can guard against having to pay a larger number of dollars

than anticipated. If the transaction were to be denominated in pounds, and the pound does appreciate, ₤100 million would cost more than $219.8 million, causing cost overruns. If the contract is still in the negotiation stage, the U.S. can (a) bargain for a price lower than ₤100 million, or (b) press for the right to have the transaction denominated in dollars. The forecast can also be used after a contract has been entered into. If the U.S. has agreed to pay in pounds, and subsequently it appears that the pound is likely to appreciate, efforts may be made to speed up payments, since a given number of pounds should cost more dollars in the future.

Foreign Sales: Now let us consider a contract for the sale of landing gear to Britain for ₤10 million, or $21.98 million at the mid-April exchange rate. If the pound is expected to appreciate, the U.S. should welcome the opportunity to receive payment in pounds: a contractually agreed value of ₤10 million should yield more than $21.98 million at the end of the year.

The same sort of strategy can be used for contracts with a country whose currency is predicted to depreciate against the dollar. For purchases, U.S. negotiators should try to denominate the transaction in the foreign currency, since the dollar cost of a given amount of the foreign currency is expected to decrease in the future. For sales, the U.S. should try to negotiate payment in dollars, rather than the foreign currency, which would yield less than the anticipated amount in dollars.

9. Conclusion

The results of this study suggest that discriminant analysis is a useful technique in terms of its ability to distinguish between currencies which are likely to appreciate and those which are likely to depreciate. Four economic variables are seen to be of significant importance as "leading indicators": price changes, changes in reserves, changes in money supply, and changes in the current balance. There are, of course, a number of misclassifications, the classification procedure being very similar to the standard hypothesis testing in elementary statistics. We have two partially overlapping populations, and try to determine which population an observation belongs to; the misclassifications are like the Type 1 and Type 2 errors.

Some of the misclassifications can be explained rather easily: the depreciation of the Japanese yen in 1979, in spite of favorable economic indicators in the previous period, is largely due to concern about the price and availability of oil, given the events in the Middle East and Japan's total reliance on imported oil. On the whole, the economic predictors used appear to contain substantial informational content, and provide an early warning of likely changes in exchange rates. The predictions should, of course, be corroborated by other information; the model is not meant to be a substitute for judgment.

Table 1

Countries in Model

1. Canada
2. Austria
3. Germany
4. Switzerland
5. U.K.
6. Belgium
7. Australia
8. Sweden
9. Japan
10. Netherlands
11. Norway
12. Finland
13. Turkey
14. New Zealand
15. Portugal
16. Spain
17. Italy
18. Greece
19. France
20. Denmark

Table 2

Exchange Rates: U.S. $ per Unit of Currency

Year-End Figures

	1974	1975	1976	1977	1978	1979
Canada	1.009	.984	.991	.914	.843	.856
Austria	.058	.054	.060	.066	.075	.080
Germany	.415	.381	.423	.475	.547	.578
Switzerland	.394	.382	.408	.500	.617	.633
U.K.	2.349	2.024	1.702	1.906	2.035	2.224
Belgium	.028	.025	.028	.030	.035	.036
Australia	1.327	1.257	1.086	1.141	1.151	1.106
Sweden	.245	.228	.242	.214	.233	.241
Japan	.00332	.00328	.00342	.00417	.00514	.00417
Netherlands	.399	.372	.407	.439	.508	.525
Norway	.192	.179	.193	.195	.199	.203
Finland	.282	.260	.265	.249	.255	.269
Turkey	.072	.066	.060	.051	.040	.028
New Zealand	1.316	1.044	.950	1.020	1.067	.986
Portugal	.041	.036	.032	.025	.022	.020
Spain	.018	.017	.015	.012	.014	.015
Italy	.00154	.00146	.00114	.00115	.00121	.00124
Greece	.033	.028	.027	.028	.028	.026
France	.225	.223	.201	.213	.239	.249
Denmark	.177	.162	.173	.173	.196	.186

Figure 1

British Pound

German Mark

Japanese Yen

1974   1975   1976   1977   1978   1979   1980

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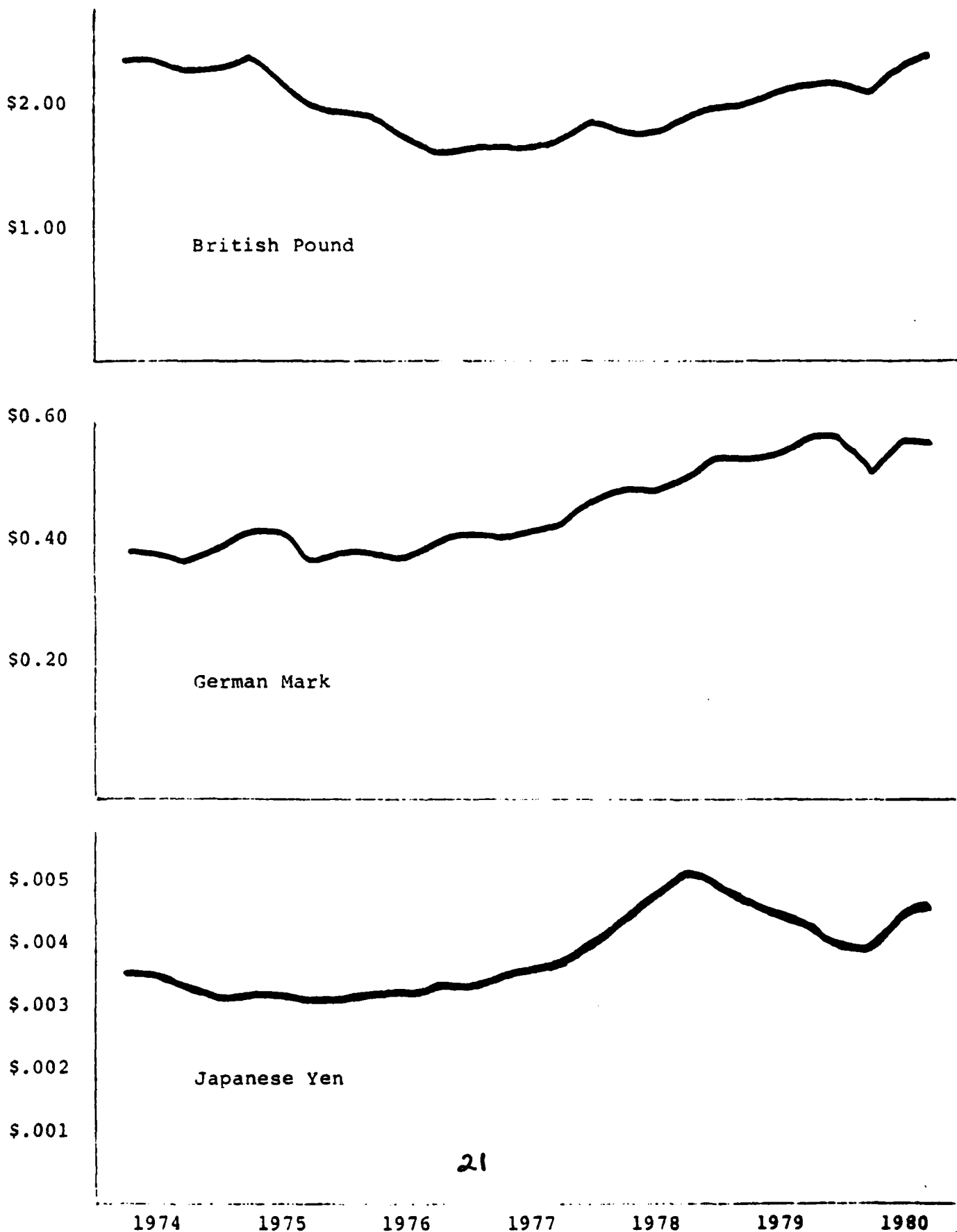
Table 3

Misclassifications, 1974-79

		1974	1975	1976	1977	1978	1979
1.	Canada		d	a	d	d	
2.	Austria		d				
3.	Germany		d				
4.	Switzerland		d				
5.	U.K.				a		
6.	Belgium		d	a			
7.	Australia				a		d
8.	Sweden						
9.	Japan						d
10.	Netherlands		d	a			
11.	Norway		d				
12.	Finland			a	d		
13.	Turkey	a					
14.	New Zealand				a		
15.	Portugal	a					
16.	Spain	a				a	
17.	Italy					a	
18.	Greece				a	d	
19.	France			d	a		
20.	Denmark			a			d

a: Currency actually appreciated, but classified as depreciating

d: Currency actually depreciated, but classified as appreciating

Table 4

Validation - Model Predictions for 1979

	Country	Discriminant Score	Predicted Group	Actual Group
1.	Canada	0.592	1	1
2.	Austria	1.893	1	1
3.	Germany	1.568	1	1
4.	Switzerland	1.681	1	1
5.	U.K.	0.226	1	1
6.	Belgium	1.124	1	1
7.	Australia	0.796	1	2
8.	Sweden	0.556	1	1
9.	Japan	1.517	1	2
10.	Netherlands	1.565	1	1
11.	Norway	1.005	1	1
12.	Finland	1.931	1	1
13.	Turkey	-5.135	2	2
14.	New Zealand	0.006	1	2
15.	Portugal	-0.489	2	2
16.	Spain	0.094	1	1
17.	Italy	0.208	1	1
18.	Greece	-0.105	2	2
19.	France	0.946	1	1
20.	Denmark	1.374	1	2

[1] International Monetary Fund, _International Financial Statistics_. OECD, _Main Economic Indicators_.

[2] Of the NATO members, Iceland is omitted because of inadequate data, and Luxembourg because its currency is tied to the Belgium franc. Sweden and Switzerland, while having no formal defense treaties with the U.S., are included because they are major arms producers.

[3] It should be mentioned that in this study currencies are classified as appreciating or depreciating purely on the difference between the January 1 and December 31 exchange rates, and no consideration is given to movements during the year. Such movements can be quite significant, as shown in Figure 1, where quarterly exchange rates for three currencies--the British pound, the German mark, and the Japanese yen--are plotted. It is possible that a random deviation at the end of the year could cause a currency to be misclassified with respect to its basic trend. Along the same lines, the model predictions refer to currency movements over one calendar year only.

[4] As a practical matter, figures are not available immediately. The time lag in the publication of the data depends on the country and the variable in question. To improve the practical applicability of the model, we use those variables which are published with the least delay, and are at the same time good predictors. The variables selected are available within 3-4 months for all countries except Turkey, i.e., end of December figures are available by April. Thus, in effect, we can use the model to get 8-9 months' warning of likely currency changes.

[5] The current balance variable could not be calculated as a simple ratio of rates of growth, since the figures could be positive as well as negative. Thus, we took the current balance in a given year and compared it to the average current balance for the previous five years, to see if there was an improvement or a deterioration as compared to the "normal" experience. As an example, if the current balance for a country for 1978 showed a deficit of -40, when the average deficit in the previous five years had been -30, this was a deterioration of 33%. We would then use an index of 67 for this country. (No change would give an index of 100, a 20 improvement would give an index of 120, etc.) The corresponding index for the U.S. would then be subtracted from this to get the figure used in our calculations.

[6] The wholesale price index (WPI) has a theoretical advantage over the consumer price index (CPI) as far as the effects on currency movements are concerned. The CPI includes many items that are not traded internationally, the most important being services (medical, educational, etc.). The WPI includes fewer items that are not tradable. Foreign exchange rates should be affected more by the prices of traded goods than by the prices of non-traded goods.

However, for predictive purposes, we can use the CPI. It is published sooner than the WPI for most countries, and the performance in the model is quite similar.

[7] We are placing ourselves in the position of an analyst who knows, at the beginning of 1979, the values of the independent variables, but does not know which way each currency would move in the course of 1979.

[8] It may be noted that the signs are the opposite of those in our previous 2-group classification. This is because the Z-scores have been reversed; now, the higher the Z-score, the weaker the currency is judged to be. The reason for this inversion is the overwhelming importance of the price variable.

[9] If the SPSS Discriminant Analysis program is used at this stage, the Z-score as well as the predicted movement of each currency is obtained by computer. In the absence of a computer, the method outlined in the text can be used.

APPENDIX 1

Geometric Representation of Discriminant Analysis

The geometry of linear combinations can be illustrated with a two variable example. The variables are denoted X and Y, corresponding to, say, reserves and money supply. We can represent the variables by the axes of a rectangular co-ordinate system, and then show how a linear combination of these variables can be represented in the same figure.

In Figure 1, P_1 and P_2 represent two countries. For country 1, the reserve variable has a value of 2, and the money supply variable a value of 5. The corresponding values for country 2 are 7 and 4. P_1 and P_2 have the co-ordinates (2,5) and (7,4) on the X, Y plane.

A linear combination of the variables X and Y, such as $Z = 4X - 3Y$ can be shown on a separate axis. This Z axis is located by obtaining the point Q whose co-ordinates on the (X,Y) plane are equal to the weights given to X and Y respectively, and drawing a line passing through the origin 0 and Q. In our example, the transformed variable is $Z = 4X - 3Y$; thus, we find the point Q with X = 4 and Y = 3, and join 0 and Q. Perpendiculars dropped from P_1 and P_2 to 0Q (the axis representing Z) locate the transformed values Q_1 and Q_2, corresponding to P_1 and P_2. Q_1 and Q_2 are at the proper _relative_ distances from 0: since $Z = 4X - 3Y$, the Z scores for our two countries are $4(2)-3(5) = -7$ and $4(7)-3(4) = 16$ respectively. It may be verified that $0Q_2$ is 16/7 or 2.3 times as long as $0Q_1$.

Figure A-1

$$Z = 4X - 3Y$$

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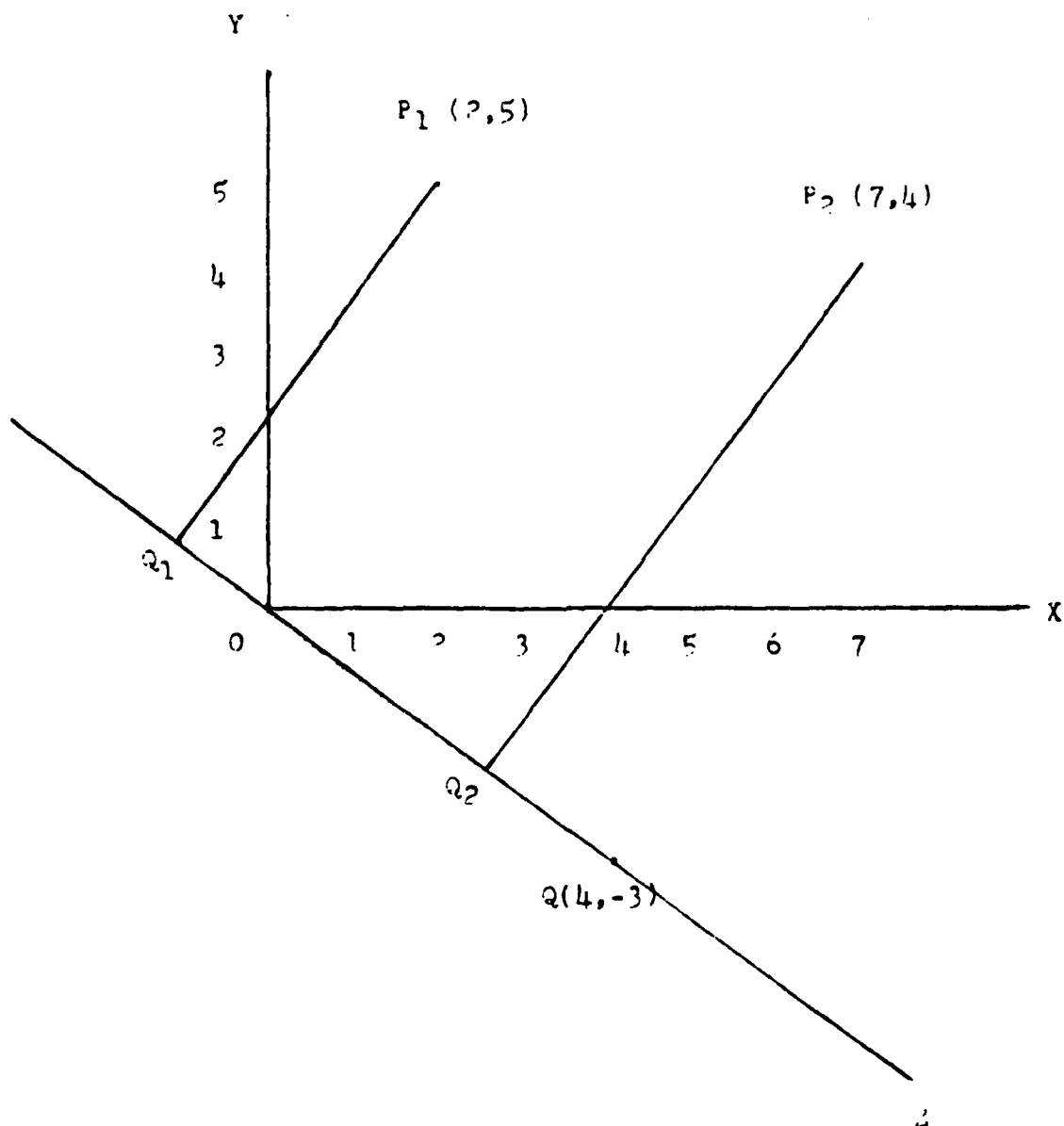
Figure A-1 shows how a two dimensional observation can be converted into a one dimensional one, and represented along a new axis by a linear combination of the original two variables. The same principle holds for linear combinations of any number of variables, though it is not possible to demonstrate such transformations in a concrete geomatric diagram if there are more than two variables to start with.

Returning to the two variable case, we can project a swarm of points representing a group--say appreciating countries--to the transformed axis Z. In Figure A-2, the centroid C_1 of the swarm is located by the mean values of X and Y (say 7 and 6) in the group. This centroid, when projected on the Z axis, takes the value $4(7)-3(6) = 10$, and the group can be shown as a distribution centered at that point.

Similarly, a second swarm of points, representing, say, depreciating countries, can be shown on the (X,Y) plane, centered on C_2. This group can also be transformed into the Z axis, and shown as a univariate distribution centered on the projection of C_2. There is some overlap between the two distributions; the objective of discriminant analysis is to find the Z axis (and determine the weights of X and Y) which best separates the two groups.
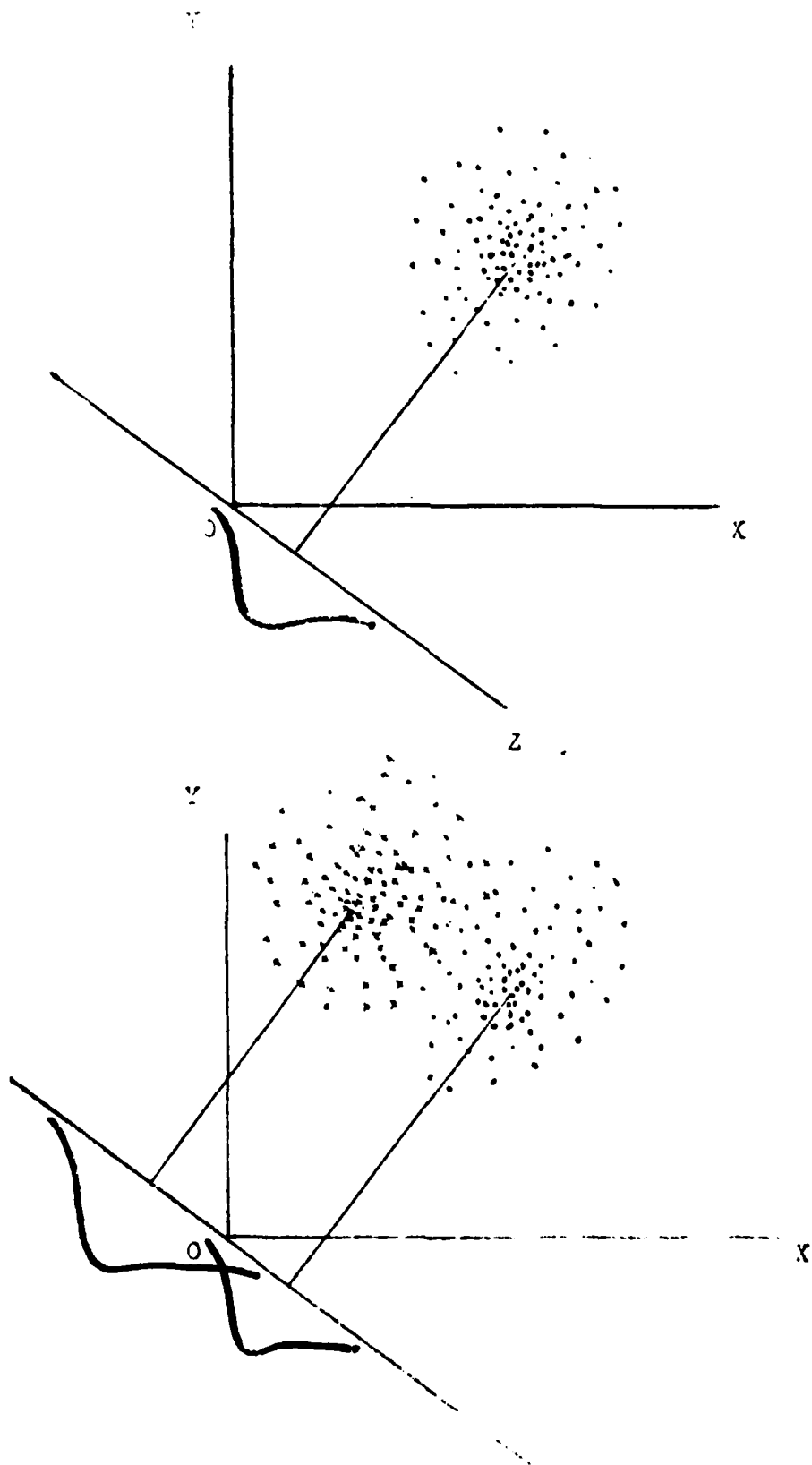
Appendix 2

```
DEFAULT SPACE ALLOCATION..    ALLOWS FOR..   102 TRANSFORMATIONS
WORKSPACE    71680 BYTES                     409 RECODE VALUES + LAG VARIABLES
TRANSPACE    10240 BYTES                    1641 IF/COMPUTE OPERATIONS

PUN NAME       DISCRIMINATE EXCHANGE RATE DATA
FILE NAME      EXRATE
VARIABLE LIST  NM,RMKT,ROFF,M1,M2,DRATE,WHRATE,CONRT,EXOIM,LABC,UNLAB, /
               ACTPRE,SPECPRE,FORSPOT,CURBAL,CHANGE
INPUT FORMAT   FIXED(A4,1X,10(F4.2,1X)F5.3,1X,F5.3,F6.0,F1.0)
```

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE	FORMAT	RECORD	COLUMNS
NM	A 4	1	1- 4
RMKT	F 4. 2	1	6- 9
RCFF	F 4. 2	1	11- 14
M1	F 4. 2	1	16- 19
M2	F 4. 2	1	21- 24
DRATE	F 4. 2	1	26- 29
WHRATE	F 4. 2	1	31- 34
CONRT	F 4. 2	1	36- 39
EXOIM	F 4. 2	1	41- 44
LABC	F 4. 2	1	46- 49
UNLAB	F 4. 2	1	51- 54
ACTPRE	F 5. 3	1	56- 60
SPECPRE	F 5. 3	1	62- 66
FCPSPCT	F 5. 3	1	68- 72
CURBAL	F 6. 0	1	73- 78
CHANGE	F 1. 0	1	79- 79

```
THE INPUT FORMAT PROVIDES FOR 16 VARIABLES.     16 WILL BE READ
IT PROVIDES FOR 1 RECORDS ('CARDS') PER CASE.   A MAXIMUM OF  79 'COLUMNS' ARE USED ON A RECORD.

INPUT MEDIUM   CARD
SUBFILE LIST   PER1(20) PER2(20) PER3 (20) PER4 (20) PER5 (20) PER6 (20)
VALUE LABELS   CHANGE (1) APPRECIATE (2) DEPRECIATE /
VAR LABELS     NM,RMKF / RMKT RESERVES GOLD AT MKT /
               ROFF, RESERVES GOLD AT OFF / M1 MONEY M1 /
               M2, MONEY M2 / DRATE, DISCOUNT RATE /
               WHRATE, WHOLESALE RATE / CONRT, CONSUMER RATE /
               EXOIM, EXPORT-IMPORT RATIO / LABC, UNIT LABOR COST /
               CHANGE, EXCHANGE RATE CHANGE /
DISCRIMINANT   GROUPS = CHANGE (1,2) /VARIABLES = ROFF,M1, CONRT, CURBAL /
               ANALYSIS = RCFF,M1,CONRT, CURBAL /
               METHOD = WICKS /
OPTIONS        5,6,11,12
STATISTICS     ALL
COMMENT        DATA CARDS WERE READ IN THIS ORDER
COMMENT        CANACA
```

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DISCRIMINATE EXCHANGE RATE DATA   07/17/80   P

```
COMMENT    AUSTRIA
COMMENT    GERMANY
COMMENT    SWITZERLAND
COMMENT    UNITED KINGDOM
COMMENT    BELGIUM
COMMENT    AUSTRALIA
COMMENT    SWEDEN
COMMENT    JAPAN
COMMENT    NETHERLANDS
COMMENT    NORWAY
COMMENT    FINLAND
COMMENT    TURKEY
COMMENT    NEW ZEALAND
COMMENT    PORTUGAL
COMMENT    SPAIN
COMMENT    ITALY
COMMENT    GREECE
COMMENT    FRANCE
COMMENT    DENMARK
```

***** WARNING *****   OPTIONS 13 THRU 19 AND STATISTICS 7, 8 ARE NOT YET IMPLEMENTED AND WILL BE

***** THIS DISCRIMINANT ANALYSIS REQUIRES   4784 BYTES OF WORKSPACE *****

READ INPUT DATA

31

DISCRIMINATE EXCHANGE RATE DATA

DISCRIMINANT SCORES

SUBFIL	CASE SEQNUM	MISSING VALUES	ACTUAL GROUP	HIGHEST GROUP P(X/G)	P(X)	2ND HIGHEST GROUP	P(G/X)	DISCRIMINANT FUNC 1
PER1	1	0	1	1	1.000	0.589	2	0.411	0.244
PER1	2	0	1	1	1.000	0.575	2	0.425	0.196
PER1	3	0	1	1	0.582	0.764	2	0.236	0.955
PER1	4	0	1	1	1.000	0.667	2	0.384	0.539
PER1	5	0	1	1	1.000	0.616	2	0.322	0.343
PER1	6	0	2	1	0.998	0.678	1	0.462	0.582
PER1	7	0	2	2	0.812	0.538	1	0.140	-0.202
PER1	8	0	1	1	0.676	0.860	2	0.334	0.514
PER1	9	0	2	2	1.000	0.666	1	0.226	-1.004
PER1	10	0	2	1	0.976	0.774	2	0.425	0.196
PER1	11	0	1	2 **	1.000	0.575	1	0.256	-0.863
PER1	12	0	2	2 **	0.991	0.744	1	0.437	-0.420
PER1	13	0	2	2	0.949	0.599	1	0.293	-0.28A
PER1	14	0	2	1	0.948	0.563	2	0.454	0.83A
PER1	15	0	1	1	0.999	0.707	2	0.379	0.230
PER1	16	0	2	2 **	0.998	0.546	1	0.277	-0.507
PER1	17	0	2	1	0.948	0.621	2	0.459	0.073
PER1	18	0	1	1	1.000	0.723	2	0.344	0.494
PER1	19	0	2	1	0.999	0.541	2	0.415	0.230
PER1	20	0	2	1	0.956	0.656	2	0.305	0.651
PER2	1	0	2	2 **	0.999	0.585	1	0.367	-0.426
PER2	2	0	2	1	0.948	0.638	2	0.406	0.768
PER2	3	0	2	2 **	0.999	0.723	1	0.437	-0.401
PER2	4	0	2	2 **	0.944	0.594	1	0.491	-0.153
PER2	5	0	1	2 **	0.000	0.563	1	0.277	-0.100
PER2	6	0	2	1	0.996	0.658	2	0.302	0.642
PER2	7	0	1	1	0.609	0.698	2	0.406	0.800
PER2	8	0	2	2	0.999	0.594	1	0.397	0.263
PER2	9	0	2	2 **	0.944	0.603	1	0.358	-0.297
PER2	10	0	2	2 **	1.000	0.642	1	0.146	-0.580
PER2	11	0	2	2	0.837	0.854	1	0.038	-0.608
PER2	12	0	2	2	0.217	0.962	1	0.231	-2.889
PER2	13	0	2	2	0.179	0.769	1	0.397	-1.119
PER2	14	0	2	2	1.000	0.648	1	0.173	-0.602
PER2	15	0	2	2	0.066	0.603	1	0.437	-0.435
PER2	16	0	2	2	0.000	0.827	1	0.228	-0.432
PER2	17	0	2	2	0.999	0.627	1	0.391	-0.521
PER2	18	0	2	2	0.978	0.563	1	0.401	-0.289
PER2	19	0	1	1	1.000	0.772	2	0.250	-1.131
PER2	20	0	1	1	0.999	0.609	2	0.176	-0.319
PER3	1	0	2	2 **	0.585	0.599	1	0.482	-0.281
PER3	2	0	2	2 **	0.911	0.750	1	0.285	-0.888
PER3	3	0	2	1	0.999	0.824	2		-1.416
PER3	5	0	2	2 **	0.997	0.518	1		-0.132
PER3	6	0	1	2 **	0.000	0.715	1		-0.871

PERC 2	0	1	0.769	0.871	2 0.129 1.596
PERC 3	0	1	0.927	0.816	2 0.184 1.230
PERC 4	0	1	0.510	0.825	2 0.175 1.284
PERC 5	0	1	0.558	0.541	2 0.459 0.074
PERC 6	0	1	0.588	0.753	2 0.247 0.903
PERC 7	0	2 ****	0.969	0.687	2 0.313 0.616
PERC 8	0	1 ****	1.007	0.632	2 0.368 0.402
PERC 9	0	2	0.927	0.816	2 0.184 1.230
PERC 10	0	1	0.864	0.832	2 0.168 0.328
PERC 11	0	2	0.992	0.741	2 0.759 0.850
PERC 12	0	2	0.743	0.876	2 0.124 1.641
PERC 13	0	1	0.002	0.991	1 0.009 -0.175
PERC 14	0	2	0.644	0.511	1 0.489 -0.107
PERC 15	0	2	1.000	0.581	2 0.419 0.354
PERC 16	0	1	0.597	0.555	2 0.445 0.124
PERC 17	0	2	0.558	0.533	2 0.467 -0.048
PERC 18	0	1	0.527	0.538	1 0.462 -0.201
PERC 19	0	2	0.565	0.729	2 0.271 -0.794
PERC 20	0	1 ****	0.545	0.804	2 0.196 1.163

PREDICTION RESULTS -

ACTUAL GROUP	NO. OF CASES	PREDICTED GRCUP MEMBERSHIP GP. 1	GP. 2
GROUP 1 APPRECIATE	69.	54 / 78.3%	15 / 21.7%
GROUP 2 DEPRECIATE	51.	15 / 29.4%	36 / 70.6%

PERCENT OF "GROUPED" CASES CORRECTLY CLASSIFIED: 75.00%

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MED

8